U.S. Geological Survey

Deer Trail Expanded Monitoring Program

2005 through 2011

9/6/2005

Introduction

The USGS Deer Trail Expanded Monitoring Program for 2005 through 2011 includes monitoring, research, and data interpretation proposed for the biosolids-application area operated by Metro Wastewater Reclamation District near Deer Trail, Colo. This is called a monitoring program for consistency with terminology used by the stakeholders. However, the program as proposed includes routine data collection, research, and interpretation of data from this program with respect to previous U.S. Geological Survey (USGS) findings from 1993-2003. This program is planned by the USGS and will be done by the USGS in cooperation with Metro Wastewater Reclamation District (Metro). Additional funding partners can be included as available. The study area (figure 1) is Metro's biosolids-application properties and surrounding private property east of Deer Trail, Colorado (subsequently referred to as "near Deer Trail").

This proposed program is presented as separate study components for ground water, sediment, biosolids, soil, crops, and air. Each of these separate study components could be conducted as a stand-alone study. However, the combination of study components that makes up the base monitoring program is very much interdependent with respect to components, both economically and scientifically. In addition to the base monitoring program for ground water, streambed sediment, biosolids, soil, and crops, selected proposal options for other study components will be incorporated during the study. Three major options have been proposed, but additional options and variations (such as additional sites monitored or increased frequency of monitoring) can be considered.

Work has been planned and priced by calendar year, based on costs for USGS fiscal year 2005. The scope of work has been considered for 6 years of data collection (2005, 2006, 2007, 2008, 2009, and 2010) and one year of report preparation, data documentation, and archive (2011). No sampling, analysis, or other data collection is planned for year 2011 in this program. The exact scope of work will be evaluated annually to enable the program to respond to significant findings and new issues.

Communication products for this monitoring program will have all study components reported together whenever possible and are planned to include:

- Annual progress reports containing available high-priority data,
- USGS data reports: 3 printed reports (2004-2006, 2007-2008, 2009-2010),
- A presentation about progress and preliminary results and a discussion of next steps at a meeting for all stakeholders once each year,
- Meetings with or presentations to smaller groups of stakeholders at least annually,
- A final interpretive USGS report for 2004-2010, and
- Additional presentations and meetings as needed and as USGS staff are available.

Overview of the planned study components:

Study component	Task	Year 2005	Year 2006	Year 2007	Year 2008	Year 2009	Year 2010	Year 2011
All	Annual presentation and meeting with full stakeholder group	X	X	X	X	X	X	X
All	Prepare data report			X		X		X
All	Prepare interpretive report							X
All	Review, compile, and interpret data	X	X	X	X	X	X	X
Ground-water base program	Program coordination and communication (including meet with stakeholders)	X	X	X	X	X	X	X
Ground-water base program	Sample 4 wells once for organic wastewater compounds	X						
Ground-water base program	Sample 5 alluvial wells quarterly for inorganic constituents	X	X	X	X	X	X	
Ground-water base program	Sample 2 bedrock wells annually for inorganic constituents	X	X	X	X	X	X	
Ground-water study: nitrate- source study	Sample 4 shallow wells and source materials once for stable isotopes	X						
Ground-water study: revisit 27 remaining monitoring wells	Visit, inspect, measure water level, and possibly sample for inorganic constituents once				X			
Streambed-sediment base program	Collect 1 pair of samples annually after runoff, if possible	X	X	X	X	X	X	
Biosolids base program	Receive biosolids samples monthly from MWRD and analyze for inorganic constituents	X	X	X	X	X	X	
Biosolids base program	Analyze 2 biosolids samples and 2 leachates for organic wastewater compounds	X						
Soil base program	Sample for inorganic constituents at biosolids-applied and corresponding control fields						X	
Crop base program	Receive combined grain samples from MWRD and analyze for inorganic constituents		X		X		X	
Air-monitoring study	Install sample-collection containers and sample for inorganic constituents at a biosolids-applied field and a corresponding control field		X					

Please note that at this time, detailed descriptions ("U.S. Geological Survey Proposal's") are provided only for the study components that will be active during 2005. Detailed descriptions of the other study components are available on request.

U.S. Geological Survey Proposal

A: Ground Water Near Deer Trail, Colorado

Base Program: Ground-water quality and hydrology

Question:

Are biosolids applications on the Metro properties near Deer Trail adversely affecting the quality of the alluvial and bedrock aquifers in the vicinity?

Concerns:

Biosolids applied to the land surface could affect the quality of shallow ground water directly through 1) contaminated recharge or 2) infiltration through contaminated soils or sediments (remobilization). Biosolids can also affect the quality of shallow ground water indirectly through 1) tilling that mobilizes or changes subsurface constituents, or 2) contributions to natural processes such as nitrification. Discharge from contaminated alluvial ground water could contaminate 1) surface water (ponds or streams), or 2) bedrock water-supply aquifers.

The Metro properties near Deer Trail are located at the eastern edge of the Denver Basin. The Laramie-Fox Hills aquifer is part of the Denver Basin aquifers and is the bedrock aquifer used as a water supply in this area. The Fox Hills Formation crops out on and adjacent to the Metro properties, and the Laramie-Fox Hills aquifer has both recharge and discharge zones. Biosolids applied to the land surface could therefore affect the quality of the bedrock ground water directly through 1) recharge from water infiltrating through contaminated soils or sediments (remobilization), 2) recharge from contaminated surface water, or 3) recharge from contaminated alluvial ground water. Biosolids can also affect the quality of bedrock ground water indirectly through 1) tilling that mobilizes or changes subsurface constituents, or 2) contributions to natural processes such as nitrification. Discharge from contaminated bedrock ground water could contaminate 1) surface water (ponds or streams), 2) alluvial aquifers, or 3) water-supply wells.

USGS studies from 1993-2004 indicate that the alluvial and bedrock aquifers are in close hydraulic connection in the study area, and that water-levels in the shallow wells declined during 1999-2004. These studies also indicate that concentrations of chloride, sulfate, nitrate, boron, iron, manganese, and selenium exceeded Colorado ground-water standards at one or more wells. Nitrate concentrations at well D6 significantly (alpha=0.05) exceeded the Colorado regulatory standard for Human Health. Concentrations of nitrate, copper, molybdenum, and selenium had significant (alpha =0.05) upward trends at one or more wells during 1999-2003. The upward trend in nitrate concentration at well D6 could be caused, in part, by biosolids applications. Concentrations of inorganic biosolids-signature elements in the ground water indicate that ground water at wells D6, D25, DTX1, and possibly DTX2 and D17 are more likely affected by biosolids applications than ground water at the other monitoring wells of the study area. However, these results are not conclusive because of natural contributions from geochemical sources and likely old apparent ground-water ages at wells D6, D17,

and D25. Some other property or chemical presence, such as organic wastewater compounds, that is not possibly characteristic of natural soil, rock, ground water or surface water of the area is needed to determine if biosolids could possibly have affected ground-water quality. For land-management purposes, it would be useful to know if ground water at this location has been affected by biosolids applications or other agricultural practices and is vulnerable to additional inputs of nitrogen from the land surface.

Objectives:

1. To determine whether concentrations of nitrate, arsenic, cadmium, copper, chromium, lead, mercury, molybdenum, nickel, selenium, tungsten, and zinc in the aquifers are significantly greater than any appropriate regulatory limits.

2. To determine whether concentrations of nitrate, arsenic, cadmium, copper, chromium, lead, mercury, molybdenum, nickel, selenium, tungsten, and zinc are increasing with time in the aquifers in the vicinity of biosolids-application properties.

3. To evaluate organic wastewater compounds (OWC's) as potential indicators (tracers) of biosolids or other waste products such as animal manure, septic systems, or pit toilets.

4. To evaluate the hydrologic interaction of the Laramie-Fox Hills aquifer with the alluvial aquifers along the eastern margin of the Denver Basin (in the vicinity of the Metro properties) to assess vulnerability of the Laramie–Fox Hills aquifer to contamination from biosolids.

Approach:

1. & 2. Monitoring wells in the aquifers previously were installed by the U.S. Geological Survey (USGS) in the drainage valleys near Metro property boundaries and at two downgradient mixing locations. At least six alluvial wells will be sampled quarterly, and two Laramie-Fox Hills (bedrock) aquifer wells will be sampled annually. Analyses will include nitrate and ammonia nitrogen, arsenic, cadmium, copper, chromium, lead, mercury, molybdenum, nickel, selenium, tungsten, and zinc, as well as well as other dissolved and total nutrients, dissolved major ions and trace elements, and physical properties. Two additional ground-water samples (analyzed for full inorganic chemistry) will be collected by the USGS from the monitoring-well network each year if no streambed-sediment samples can be collected that year. All ground-water samples will be collected using appropriate USGS protocols. Water levels and field parameters will be measured with each sample collected to provide context for the chemical analyses. Sufficient field blanks will be analyzed to enable sample bias (laboratory plus field) to be evaluated with at least 90 percent confidence after 6 years of monitoring. Sufficient field replicates will be analyzed to enable sample variability (laboratory plus field) to be evaluated with at least 90 percent confidence after 6 years of monitoring. The concentration data will be compared with appropriate regulatory limits for selected constituents. Trends in concentration of selected constituents will be evaluated. The concentration data also will be evaluated for a possible "biosolids signature."

3. Samples will be collected once from four shallow wells considered more likely to have been affected by biosolids applications. These samples will be analyzed for organic

wastewater compounds, along with a field blank and a replicate sample. Two Metro biosolids samples also will be analyzed for organic wastewater compounds as part of the USGS Toxics Program research study. In addition, two fresh biosolids samples from Metro and two field-aged Metro biosolids samples will be leached in a laboratory procedure, and these leachate samples also will be analyzed for organic wastewater compounds. The ground-water, biosolids, and leachate data will be compared for presence and concentrations of organic wastewater compounds.

4. Water levels of the monitoring-well network will be measured approximately monthly. For this approach, the monitoring-well network includes 17 alluvial-aquifer wells and 4 bedrock-aquifer wells. Two of the bedrock-aquifer wells are nested wells screened in 2 different zones of the Laramie-Fox Hills aquifer. These nested wells also have at the same site at least one well screened in the overlying alluvial aquifer. These sites with the nested wells are considered recharge-evaluation sites. The southernmost recharge-evaluation site has USGS continuous-recorder instrumentation for precipitation and ground-water altitudes of 3 different zones. This USGS instrumentation site (known as electronic data logger or EDL) for the Laramie-Fox Hills aquifer is on private property (west of the north Metro property) and will be continued. One USGS instrumentation site (known as a data-collection platform or DCP) is at DTX2 on the north Metro property where Badger Creek exits the Metro property to continuously monitor precipitation amounts and air temperature, and ground-water temperature and level, and will be continued. The two remaining DCP's on the central (at well D25) and south Metro properties (at well DTX5) will be shut down. Water level, water-temperature, and climate data will be used to evaluate ground-water recharge and climate effects. Comparisons of water-level altitudes and patterns will be used to evaluate vertical hydraulic gradients between aquifers.

Please refer to text and tabular "overview of the planned study components" in the introductory section for a description of study products and a work plan.

Monitoring sites:

Any sites of interest to the stakeholders could be monitored; however, some sites are critical for a scientifically sound monitoring program that meets the stated objectives. The highest priority for sampling is wells most likely to have been affected by biosolids applications as indicated by the results of the 1999-2003 USGS study. Those wells are D6, D17, D25, DTX1, and DTX2. Therefore, these 5 wells will be sampled quarterly for inorganic constituents, and 4 wells will be sampled once for organic wastewater compounds. The second highest priority for sampling is the downgradient Denver Basin bedrock wells because of the close hydraulic connection between the bedrock and alluvial aquifers, and because the bedrock aquifer is used for domestic and agricultural supply. Those wells are DTX8A and DTX10A, and these two wells will be sampled annually for inorganic constituents. The third highest priority for sampling is geographical coverage of the three Metro properties, so well DTX6 on the south property will be sampled if streambed-sediment samples are not collected in any given year. Additional USGS monitoring wells on or off the Metro properties could be sampled to provide information about chemical and hydrologic variability of the alluvial aquifers. Depth to water will be measured at 23 of the USGS monitoring wells, including 4 bedrock-aquifer wells.

Monitoring wells installed by the USGS during 1993-2002 are available for this phase of monitoring. If any of these wells do not have sufficient water for sampling, other USGS monitoring wells in the vicinity will be substituted for sampling.

Benefits:

This approach will yield data useful for objectively evaluating water quality and hydrology of the alluvial and bedrock aquifers in the vicinity of the biosolids-applied properties, as well as changes in water-quality parameters over time. Hydrologic and geochemical processes can be evaluated because extensive hydrologic and water-quality information will be collected.

This approach will verify and further develop the concept of biosolids signature that was introduced as a result of the 1999-2003 study.

The information regarding organic wastewater compounds can be used to evaluate the occurrence and mobility of these compounds in biosolids and in a semi-arid environment. This information also can be used to determine future research priorities for organic wastewater compounds associated with biosolids.

Instrumentation sites (DCP's) will be useful for evaluating ground-water recharge and hydrologic variability. Rainfall data from these sites can also be used for determining sediment and surface-water sampling times, as well as for crop or livestock management by nearby property owners.

Monitoring the well pairs will enable evaluation of the hydrologic connection between the Denver Basin bedrock and alluvial aquifers (including possible recharge zones) in the vicinity of the Metro properties. Comparing these data for 2004-2010 with data for 1999-2003 can indicate the variability in these relations under different climate scenarios.

Limitations:

This approach may not yield sufficient water-quality information to definitively prove that biosolids applications are causing the changes in water quality (analyses of natural isotopes or wastewater tracers, in addition to age dating, are needed to determine sources). "Background" (pre-biosolids or even pre-farming) water quality can not be determined because biosolids have been at this site for several years and much of the property has been farmed since the 1970's.

Unless a monitoring well is located in every drainage valley that enters or leaves the Metro property, alluvial-aquifer quality cannot be completely quantified. However, about fifty drainages enter or leave the Metro properties, so monitoring a few of the major drainages on each of the three Metro properties (with or without downgradient sites where tributary aquifers mix) is a reasonable initial approach. If concentrations at the Metro borders or mixing sites are above regulatory limits, then additional wells could be installed upgradient on the Metro properties or downgradient on private property. Sampling only the alluvial wells along property boundaries that are most likely to have already been affected by biosolids applications (as indicated by the results of the 1999-2003 study) will not provide any information about whether other ground-water sites in the vicinity have been affected by biosolids applications. Additional wells would need to be monitored to provide that information.

The USGS study on the Metro Central property indicates that nitrate concentrations in alluvial ground water in this area can fluctuate at least 19 milligrams per liter within 3 months between summer and fall. Therefore, sampling the wells quarterly for nutrients will not document all nutrient concentrations and may result in underestimated maximum nitrate concentrations. If maximum nitrate concentrations are of concern, then wells will need to be sampled more frequently than quarterly.

Hydrologic characteristics of the Laramie-Fox Hills aquifer are variable. Unless many monitoring wells and well pairs are installed in the major drainage valleys containing both bedrock and alluvial aquifers (such as the Muddy Creek drainage valley), every recharge and discharge area of the Laramie-Fox Hills aquifer cannot be identified. Monitoring recharge-evaluation sites downgradient from the Metro properties are important in evaluating regional ground-water quality; but changes in water quality at these sites could not be attributed to a specific land use (such as biosolids applications) unless the scope of the monitoring program is expanded considerably.

Chemical characteristics of the Laramie-Fox Hills aquifer also are variable. Routinely sampling only two bedrock wells will not fully evaluate the water quality of the Denver Basin aquifers along the eastern margin of the Denver Basin but will provide information about bedrock water quality and changes at specific areas of interest. Sampling only the bedrock wells (and not the two new paired alluvial wells) will satisfy the objectives of this program, but will not enable changes in bedrock water quality to be directly linked to alluvial water quality at these sites. Results of the 1999-2003 study indicate that chemical characteristics of the Laramie-Fox Hills aquifer do not fluctuate as much as those of the alluvial aquifers so annual sampling is proposed. However, annual sampling of the two wells in this bedrock aquifer may not provide further information about chemical variability, especially if that variability increases.

Schedule of initial monitoring:

Monitoring ground water in the vicinity of the Metro properties can begin within one month after the contract is finalized with a signed funding agreement. The monitoring wells were installed previously (1993-2002). Much of the equipment is already available because it was obtained for the 1999-2003 USGS monitoring. This proposal assumes that monitoring will begin in April or May 2005.